other parts of fructification (no leaf examined); hairs of scape jointless, and not glandular. *Dendrobium nobile*: raphides abundant in very young leaves, less so in old leaves and stem, and very rare in the root. *D. pulchellum*: bundles of raphides in the stem and fleshy leaves, and very rare in the root. Leaf of another *Dendrobium*: raphides rather scanty, but large. Leaf of *Aërides odorata*: several bundles of raphides, but not abounding. Bit of leaf of *Trichotosia* (a section of *Eria*): bundles of large raphides abundant in cells, and numberless smaller raphides in the field of vision; hairs of leaf red, smooth, jointless, swollen at base, and not glandular. *Schomburgkia crispa*: bundles of raphides abundant in swollen part of stem, scarcer in its thin part and leaf; woody part of stem made up of dotted vessels. *Cattleya Mossiæ* (leaf and swollen part of stem): raphides abundant. *Phaius grandifolius*: bundles of raphides swarming in the leaves, bulb, and root-fibres; in the bulb, raphis-cells very large and hyaline, also a profusion of beautiful, conical, large starch-granules, average length $\frac{1}{266}$th, and breadth $\frac{1}{400}$th of an inch. *Brassia* (a bit of the leaf, as also in all the following): raphides, but not very plentiful. *Oncidium*: very few bundles of raphides. *Megaclinium*: raphides abundant, and a beautiful subcuticular sphæraphid tissue (Annals, Sept. 1863, Pl. IV. fig. 13); the diameter of each of the sphæraphides regularly about $\frac{1}{3200}$th of an inch. *Ansellia*: raphides rather numerous. *Bolbophyllum*: raphides pretty numerous.

Araceæ.—Among some fragments of plants to aid this inquiry, which were obligingly supplied by Mr. Cox, the excellent superintendent of the Redleaf Gardens, is part of the leaf of *Richardia æthiopica*, which I find abounding in biforines, the raphides escaping, under gentle pressure, regularly from both ends of the oval cells.

Edenbridge, Feb. 12, 1864.

Erratum.—In the February Number, page 121, line 34, *for* "classification" *read* "discrimination."

[To be continued.]

XXVI.—*On the Extent, and some of the Principal Causes, of Structural Variation among the Difflugian Rhizopods.* By G. C. Wallich, M.D., F.L.S., &c.

[Plates XV. & XVI.]

The wide range of variation manifest in the external characters of the non-testaceous Amœban and Actinophryan Rhizopods has been already discussed by me in several papers which have appeared in the 'Annals' during the course of the bygone year. On the present occasion I propose to show that amongst the testaceous genera of the same order (namely, the Proteina*) this tendency to variation is no less marked, and that it is attributable (as was stated to be the case in the non-testaceous genera) rather to the ever-fluctuating conditions of the medium by which the organisms are surrounded than to any special hereditary idiosyncrasies by which certain characters become impressed upon certain races of individuals.

The primary points to be considered are, whether the degree of variation observable in the soft parts—or actual bodies of these creatures—is at all commensurate with that which is traceable in their tests; and whether there exists such an intimate relation between the changes in figure, composition, size, and colour of the tests, and of the sarcode-bodies over which they are formed, as to indicate varying degrees of physiological advance or degradation. For it cannot be too strongly urged that, on the proper apprehension of these two questions must mainly depend our ability to discriminate between characters that are, and those that are not, of true specific value; and that every incautious addition to our lists of species, whilst inevitably operating as an obstacle in the path of those persons who are desirous of studying the biological relations of the lower forms of organic being, must also tend materially to augment the difficulties which stand in the way of a natural and easily available systematic arrangement.

As stated by me in the 'Annals' for June last (p. 452), it seems almost impossible to examine the sarcode-body of *Difflugia* and *Arcella*, on the one hand, and of *Euglypha* and some allied forms, on the other, without perceiving that in each case these organisms ought to be comprehended under a single genus. Between the degree of differentiation attained by the sarcode of *Difflugia* and *Arcella* there is nothing suggestive of more than specific distinctness. Both these forms are *Amœbæ* in the strictest sense; that is to say, their bodies consist of sarcode in which the degree of consolidation of the external layer for the time being is so complete that the outline of the surface,

* Under this designation are united by me those Rhizopods which differ from the preceding orders (namely, the Herpnemata and Protodermata) in the possession both of a definite nucleus and contractile vesicle. They are divisible into two primary families, the "Amœbina" and "Actinophryna," based principally on peculiarities presented by the sarcode-body.

The *Difflugidæ* constitute a subfamily of the *Amœbina* standing naturally apart from the remaining testaceous forms which present the Actinophryan type of ectosarc and pseudopodia, and hence constitute a subfamily of the Actinophryna under the name of the *Euglyphidæ*. (See classification of these subfamilies, at page 240).

with the exception of a small area posteriorly, is devoid of granularity, and possesses no adhesive power. Hence the pseudopodia do not coalesce unless during the inception of food. Again, the bodies of *Difflugia* and *Arcella*, as is the case in *Amœba*, exhibit a determinate anterior and posterior portion, the projection of the lobate or finger-like pseudopodia taking place only over the former region, whilst the latter serves, through an increase of the adhesive power over a small area, to furnish attachment to the fundus of the test interiorly. In both, the nucleus and contractile vesicle or vesicles, after disengagement from the test, are found to be identical in character, and to exhibit the same tendency to subdivision, at certain periods of the creature's history, that is witnessed on a larger scale in the *Amœbæ* proper. And, lastly, the reproductive process is the same as regards every known essential particular*.

In the case of the freshwater *Euglyphidæ*, although the difficulties of observation are somewhat increased in one direction, owing to their more minute size, these are more than counterbalanced in another by their freedom from mineral particles, which usually interfere with vision; and, with a little care, we are enabled to perceive that an absolute identity in the character of the soft parts pervades this group also. Indeed this identity would seem to have been recognized, inasmuch as the *genera* into which the species and their varieties have been constituted by different observers are distinguished from each other altogether by the shape, size, colour, and markings of the tests. Under a cautious examination of the sarcode-mass, we are enabled to perceive that the *Euglyphidæ* differ from the *Amœbæ* proper and *Difflugidæ*, inasmuch as their ectosarc is minutely granular, and possesses a decided degree of adhesive viscidity throughout the entire body, whilst their pseudopodia also exhibit a finely granular outline, are filiform,

* Even when the Difflugian tests are constructed of the most hyaline materials, and specimens are obtained with the slightest intermixture of extraneous matter, it is extremely difficult to trace out the appearances presented by the organs they enclose, with any approach to certainty. Indeed the attempt to do so is vain, unless we happen to meet with individuals the tests of which are constructed of mineral fragments flat enough and thin enough not to interfere materially with the passage of the rays of light. Under proper management, however, it is quite possible so to regulate the action of the compressor as to keep the soft parts more or less *in situ* after extrusion from the test; whilst we may often assure ourselves that objects within the test, supposed to be the nucleus, contractile vesicles, or food-particles, are in reality so, by carefully watching their transit as they escape under pressure,—bodies like the sarcoblasts and crystalloids, the positions of which within the endosarc are indeterminate, of course admitting of an equally satisfactory scrutiny, whether seen without or within the test.

tapering to some extent, radiate, and freely coalescent; while, coupled with and perhaps dependent on these characters, the pseudopodia of this subfamily, as if to compensate for the restricted power of locomotion possessed by them in comparison with the *Amœbæ* proper, are much more active—the rapidity with which they admit of being projected outwards or withdrawn into the test being unequalled in any other form, and presenting the most wonderful example of inherent contractility in an amorphous animal substance that is to be met with in either of the great organic kingdoms. It is hardly necessary to point out, however, that, in the absence of other characters, this peculiarity can no more be regarded as indicative of generic, or even specific, distinctness than the difference in the speed of the racer and cart-horse can be regarded as indicating their specific separation.

But it is in the features presented by the tests of the Difflugian group of freshwater Rhizopods that the tendency takes place to the inordinate modification to which allusion has been made, and enables us to perceive that it is dependent on the fluctuating condition of the water in which they live and of the mineral ingredients peculiar to the soil of each locality. For, as might naturally be expected from the protection afforded by the tests, the soft parts are uninfluenced by many of those agencies which produce changes in the external characters of the naked genera; and hence we are enabled the more readily to assure ourselves of the unity, in each case, of the generic type which pervades the two groups into which these organisms appear to me naturally to resolve themselves.

I propose, in the first place, to adduce the grounds on which I base the opinion that, with the exception of a few *permanent varieties* which exhibit a type capable of being hereditarily transmitted, the whole of the varieties may be regarded as the result, 1st, of modifications in figure, dependent in some instances on the inability of the test to sustain its own weight, and in others on its tendency to assume curvature or obliquity from the action of running water; 2ndly, of modifications in the materials of which the tests are constructed, depending sometimes on the kind of mineral substances procurable in particular localities, sometimes on a hitherto unrecognized and very remarkable union between the chitinoid basal substance (which is an exudation from the animal) and the mineral particles which that substance serves in the first instance merely to cement together; 3rdly, of modifications in size, depending probably on the age, the perfect or imperfect nutrition of the individual, and also on the capability of the test to alter its form after having become consolidated to a certain extent by the addition of mineral particles; 4thly and lastly, of modifications in colour, arising partly from the nature of the food that has been incepted by the animal, partly from the external incrustation of organic or inorganic débris, and occasionally from the depth of tint of the chitinoid basal substance.

Before proceeding, however, I may be permitted to state that the whole of the forms about to be described in these pages have not only been met with by me abroad, in the plains of Lower Bengal, in the Himalayan Mountains, on the confines of the Arctic Circle, in Labrador, and in Nova Scotia, but, excepting the two or three extreme *varietal* forms encountered only in the most remote of these localities, the whole are to be found abundantly in nearly every pool and streamlet throughout England. It may also be mentioned that my conclusions have in no case been arrived at from the examination of solitary specimens, but only after a laborious comparison of those which have occurred in sufficient numbers and in sufficiently varying stages of growth to guarantee the avoidance of exceptional examples *.

Taking the several kinds of varietal modification referred to in the order of their importance, I have, in the first place, to notice the one involving the *shape* of the test, or, as Dr. Carpenter appropriately designates it, in speaking of the Foraminifera, "their plan of growth." For if, as he has urged, this furnishes no natural basis for generic distinction in the family to which he more especially refers, in which the structure of the shell is at times highly complex, it is obvious that the plan of growth cannot afford a trustworthy distinctive character in a group of organisms the tests of which are of the simplest kind, and hence more liable to come under the operation of varying physical influences.

After having most carefully studied the several varieties of Difflugian test, and compared the characters of the whole series with due regard to the local conditions under which they were found, I have been irresistibly led to the conclusion that they have sprung from *one* primary or larval form; in other words, I conceive that the whole are referable to a single specific type, and that, whatever varietal figure the mature test assumes, such figure may be the result of peculiarities in the external conditions by which it is surrounded, and not the result of hereditary transmission in each case. So that, supposing A to represent the prevailing form of the Difflugian test in its earliest stage, under the varying conditions of the medium by which it

* The foreign materials to which I have just alluded still remain in my possession, in a mounted as well as an unmounted state; whilst all the specimens from which I have made my drawings are preserved for verification by those naturalists who are engaged in the study of the Rhizopods.

is surrounded it may ultimately assume the shape of either of the varieties W, X, Y, or Z.

Of course, it is not only possible, but highly probable, that the type of the mature variety may, in the greater number of forms, be reproduced in the progeny; but, be this as it may, there can be no doubt of the fact that, with a solitary exception, specimens are to be found in every habitat, the characters of which overlap, so to speak, those of the most closely allied varieties to such a degree as to prove that there exist no true specific limits between them; whilst it is interesting to observe that the exceptional form referred to, namely, *Difflugia spiralis* (Pl. XV. figs. 3, 3 *v* & Pl. XVI. fig. 24)*, instead of disproving the fact advanced, confirms it, as shall hereafter be shown, inasmuch as the recurved shape assumed by the test would seem to be produced by a purely mechanical agency which is only able to exert influence upon it when it approaches maturity.

It is also deserving of notice, as bearing upon the probable existence of only a single distinct specific type in *Difflugia*, that the number of mature tests in which the globular form prevails falls immeasurably short of the number of young tests exhibiting that shape†. This may, no doubt, be accounted for on the supposition that the greater proportion of this the prevailing form of young test may perish before they advance further in growth. But there are no grounds for such an assumption, since the minute tests occur wherever *Difflugiæ* are most abundant and the conditions for existence may therefore be assumed to be the most favourable; and, as already stated, every gradational variety is traceable even from this early stage. It seems much more likely, therefore, that the globular figure, as shown in Plate XV. fig. 1‡, is made to assume either of those represented in the surrounding figures 2, 3, 4, & 5, according as the earliest

* When noticing this variety of *Difflugia* (Annals, June 1863, p. 451) as having been observed by me in England for the first time, I was not aware that it had been detected so long ago as the year 1815 by M. Leclerc, and accordingly gave it the provisional name of *D. proteiformis*, var. *septifera*, in allusion to the dithalamous tendency evinced by its test. I am glad to find that I am supported by Perty in the view that it is a "monstrosity" of the form named, and not a distinct specific type.

† It may be mentioned that the most minute recognizable tests of *Difflugia* measure about $\frac{1}{1000}$th of an inch in diameter, whilst the sarcoblasts of this genus, when extruded under pressure from the test so as to be examined separately, average about $\frac{1}{2550}$th of an inch.

‡ In order to make the characters referred to in the text more readily intelligible to my readers, all references connected with the subject of varietal modification in *shape* are made to the outline-figures in Plate XV.; whilst those bearing on the composition and general outward features of the tests are made to the detailed figures of the same forms given in Plate XVI. Exceptional references will be expressly indicated.

addition of mineral matter, if cemented to a point opposite the aperture, may tend by its weight to depress the test in the direction of its axis*, and thus give rise to the flattened series of forms of which *Difflugia aculeata* is an example (fig. 4 *k*), and *Arcella vulgaris* (Ehr.) = *Difflugia vulgaris* (Wall.) is the extreme limit; or cause it to assume the elongated cylindrical outline of the mitriform series, of which such varieties as *D. acuminata* and *D. mitriformis* are mature examples, should the particles of mineral matter first employed be attached at points intermediate between the aperture and the apex of the test (figs. 2, 2 *p*, *q*, 3, 3 *a*, *b*, *c*, &c.).

It is true that in *Difflugia vulgaris* (fig. 1 *y*) the test is normally depressed even in the entire absence of all foreign matter. But it is also deserving of note that the most delicate and hyaline tests of this species are those which present the greatest degree of depression; whereas the stouter and more deeply coloured mature tests are those in which the hemispherical shape is most perfectly maintained. Here then it is quite evident that strength of the basal chitinoid material, as compared with the weight it has to support, constitutes a *mechanical* condition upon which the modifications of figure are dependent, and hence lends confirmation to the view advanced with reference to *Difflugia*, even admitting, for the sake of argument, that *Arcella* and *Difflugia* are generically distinct.

Again, where the mineral matter is so uniformly distributed over the young spherical test as to cause no deviation from its normal outline, the globular or subglobular figure is maintained, and attains its maximum development in such forms as are represented by figs. 4 & 4 *a–g*.

In another set of cases, in which the axis of the test may be rendered oblique by a preponderance of mineral particles taking place on one side, or through the pressure of a stream flowing in one direction and thus acting upon the young test whilst yet unconsolidated, the oblique or pouch-shaped series of forms is produced, of which the simplest example is devoid of horn-like appendages (figs. 5 *a*, 5 *d*); and a new variety, common in many places, but most fully developed in Greenland, namely *D. cassis* (figs. 5 *b* & 5 *c*), may be taken as the extreme example.

I have already given what I regard as the only probable ex-

* By the axis of the test is meant the imaginary line which would pass through the centre of the plane of the aperture and the apex. As the pseudopodia are invariably projected through the aperture, the extremity at which it occurs is called the anterior, the opposite being the posterior, aspect. The apex of the test is the point furthest removed from the axis of the aperture, whether reference be made to the symmetrically or asymmetrically formed series.

planation of the entire absence of young tests presenting the well-marked peculiarity of *Difflugia spiralis*, namely, that it is a modification of form produced by mechanical causes which only come into operation when the mitriform or acuminate test (figs. 2 *p*, 3 *c*, 3 *b*) approaches maturity. This may, however, be regarded as an exceptional case. But in *D. corona*, a variety found in tolerable abundance on the borders of the Gangetic Sunderbunds, and which is represented in figs. 4 *b*, 4 *c*, I have, in like manner, failed to discover young tests in which the crenulated aperture is associated with the horn-like processes seen when it is mature. Medium-sized globular tests occur, however, in which the crenulate aperture is fully developed (fig. 4 *a*); and, on the other hand, mitriform specimens, such as those shown in fig. 3, in which a varying number of crenulations around the aperture is observable. Now there is nothing to distinguish the globular form *with* the crenulate aperture (fig. 4 *a*) from the simple globular form *without* it (fig. 4 *h*), which constitutes one phase of *D. proteiformis* as given by Ehrenberg (Infusionsthierchen, taf. 9. fig. 1*b*), but the feature referred to; whilst the crenulate aperture occasionally reappears in the tuberculate variety of the latter form (fig. 4 *g*). Lastly, individuals are frequently met with of the mature *D. corona*—that is, in which the horns are fully developed,—but exhibiting a perfectly plain aperture.

Three conclusions are deducible from these facts,—the first being that neither the crenulation nor the cornua are constant in the variety named *D. corona*, singularly distinct though it appears if considered without reference to the osculant forms by which it is surrounded; the second, that there is nothing except the crenulation to distinguish the entire globular form with the crenulation (fig. 4 *a*) from the universally distributed globular variety (fig. 4 *h*); and the third, that the crenulate margin of the aperture is not even confined to the globular series of tests, but is to be seen occasionally in the mitriform varieties; whilst neither in one set of forms nor in the other is there anything like constancy in the number of the crenulations themselves.

If we turn to the series of mitriform tests, of which the beautifully proportioned variety *D. lageniformis* (fig. 2 *c*) would seem to be the culminating point, we find that the characters combining to make up this figure are gradually developed through the whole of the mitriform series, which has heretofore been subdivided, on the most trivial grounds, into four so-called species, namely, *D. proteiformis*, *D. oblonga*, *D. acuminata* (Ehr.), and *D. pyriformis* (Perty). Thus, commencing from the earlier mitriform test, as shown in fig. 2, there is an unbroken transition, both as regards extension in the longitudinal and transverse axis of the test, to the broadly ovate shape shown in fig. 2 *q*, and the almost cylindrical varieties which have been termed *D. oblonga* or *D. acuminata,* as they happen to present the acuminate or simply convex outline posteriorly (figs. 3 *t* & 3 *b*); whilst, by a compromise, as it were, between such shapes as are depicted in figs. 3 *t* & 2 *q*, we have the balloon-like or pear-shaped varieties (figs. 2 *b* & 3 *s*).

Again, taking the young test (fig. 2) as a starting-point, we occasionally meet with what, at first sight, appears to be a well-defined narrow but plain band surrounding the aperture, as shown in fig. 2 *a*. But this is by no means confined to one form of test; it is to be seen now and then in the aperture of such forms as figs. 2 *q*, 4 *h*, 4 *g*, and indeed in all the varieties of the forms represented in figs. 2 *i*, 4, & 4 *g*, and depends on the eversion of the marginal border of the basal chitinoid layer so that it overlaps the margin of the foreign particles impacted on the outer surface of the test. In short, this is the rudiment of the *lip* which becomes so largely developed in the extreme variety of the series, namely, *D. lageniformis* (fig. 2 *c*).

Now the crenulate margin of *D. corona* and the other varieties that present this character is merely a modification of the apertural band just referred to, in which the margin of the basal chitinoid layer, instead of being unbroken, is formed into a series of minute crenulations, the points of which alone reach the extreme edge of the aperture, without apparent eversion, however.

We can hardly fail to perceive that this arrangement of the apertural margin of the Difflugian test is evidently the best fitted to admit of the easy projection and retraction of the glairy pseudopodia. I believe it pervades the entire series of varieties, although more readily, or at all events more generally, recognizable in certain forms. In all we can perceive that the greatest care seems to be lavished on the selection of minute mineral particles for deposition immediately around the aperture; and, as I shall presently show, that in those examples in which there is no admixture of extraneous mineral matter, but the entire test is made up of chitinoid substance, there is evidence of a like degree of adaptative power. Were the evidence otherwise incomplete, I conceive, however, that the structure of the beautifully moulded lip of *D. lageniformis* would prove conclusive; for in it we find that whilst the mineral particles with which the rest of the test is as it were tessellated extend to the commencement of the everted portion, from that point they gradually dwindle away, until at last it is only with considerable care in the adjustment of the light and focus that we are enabled to perceive the almost hyaline margin of the overhanging lip.

Lastly, we arrive at the singular group of forms in which the test is so far asymmetrical (and in this respect differs in character from all those previously described, with the exception of *D. spiralis*), that a section passing transversely through the apertural plane would form two very unequal portions. Nevertheless it can be shown that even here there is no valid ground for assuming specific distinctness, or that the figure of the test is not determined by *extrinsic* conditions.

I have already explained how readily the slightest inequality in the distribution of the mineral particles in the earliest state of the test may cause it to assume an oblique figure, and that such figure may, without any improbability, be also imparted to it, in the young state and (as will hereafter be seen) at subsequent periods of its history, by the action of running water,—*D. spiralis* affording a marked example, in which the latter agency would seem to produce the effect in the most signal degree*. Now, although I have heretofore been unable to satisfy myself that in habitats in which there is a current, and in those in which there is none, the asymmetrically and symmetrically shaped tests respectively predominate to such an extent as to leave *no* room for doubt as to the efficacy of the second cause I have suggested, from such observations as I have made on the character of the spots from which I have obtained *Difflugiæ*, I cannot help believing that this is the case. And whilst I confine myself, at present, to stating the matter suggestively, I may mention that in three localities very widely removed from each other, and in which the nature of the land is itself evidence of the liability or otherwise to a constantly running state of the water, this preponderance seems at all events undeniable. Thus on the borders of the Sunderbunds, where the whole country is a vast swamp, there are pools perpetually fed with fresh supplies of water, but only subject to currents during the inundations occurring during the rainy season. From such pools I obtained the most highly developed varieties of the symmetrical Difflugian tests I have ever seen, namely, *D. corona* and *D. lageniformis* (figs. 2 *c* and 4 *c*),—the oblique series and even *D. spiralis* being, however, moderately represented. At Goodhaab again, in West Greenland, I obtained material from pools occurring along the course of somewhat precipitous valleys, and accordingly under the constant action of the mountain streams by which these waters were supplied.

* Fig. 3 *v* gives the outline of a normal test of the pyriform variety of *Difflugia proteiformis*, whilst the dotted outline represents an ideal view of the same test made to assume a *retort*-shape by a force acting upon it laterally and in one direction. It is an instructive fact that the semicircular fold observable in the neck of this test and the neck of an ordinary retort are precisely similar; indeed the derivation of the word "retort" explains the manner by which the curvature is effected in both cases.

In these the most highly developed forms were the oblique ones, —*D. cassis* (which may be regarded as the limit of this series, as I have already shown) attaining its extreme characters (figs. 5 *b*, 5 *c*), and, what must be considered as equally significant, the tests of the larger oblique varieties, and also of the common mitriform series, being loaded to an extraordinary degree with mineral matter, chiefly in the shape of diatoms, doubtless to render their weight greater (Plate XVI. fig. 9).

Lastly, in a locality close at hand, namely Hampstead, in little pools extending down the slopes and perpetually subject to a dribbling stream, the oblique varieties are abundant, though not attaining the extreme characters of *D. cassis*—such varieties as *D. aculeata* and *D. spiralis* being common; whilst the tests of the mitriform series are frequently covered with masses of mineral matter so large in proportion to the entire size of the tests, and so irregular, as to render it far from improbable that their weight and outline must exercise some power in enabling them to hold their ground.

But, to revert to the varietal development of the series now under notice, taking the globular young test once more as a starting-point, we find an extremely gradual transition taking place, first till we arrive at full-sized mature tests the spherical outline of which is only disturbed to the extent of making the aperture appear slightly excentric. This variety is represented in fig. 4 *k*. In the latter example, however, we perceive the hollow horn-like processes which have been regarded as indicating the species to which the name of *D. aculeata* (*Arcella aculeata*, Ehr.), has been given. Now there is not a single character to distinguish a variety of this form without horns from the common globular variety (fig. 4 *h*), save this trifling obliquity or compression. On the other hand, there is nothing to separate the horned variety (fig. 4 *k*) from *D. corona* when devoid of the crenulated aperture, but this same obliquity; for although the cornua are generally distributed only over that half of the test furthest removed from the aperture, this peculiarity is occasionally met on the side of *D. corona* by a similar asymmetrical disposition of its cornua; whilst specimens are now and then to be found of *D. aculeata* in which the cornua really form a complete circlet, but, owing to the tendency of the test to rest in a position perpendicular to the plane of the aperture, the part anterior to the aperture prevents a certain portion from being easily seen.

In the variety shown in figs. 5 *a*, *d*, & *e*, we have the transition from the plain, small, oblique test (fig. 5) to the form of *D. aculeata* shown in fig. 5 *m*. But two slight peculiarities now make their appearance,—the first being that the horns become longer and identical with the broad-based apical horn sometimes seen in the acuminate variety of *D. mitriformis* (fig. 3 *c*); whilst the second consists in a partial *inversion* of the apertural lip, instead of an *eversion*, as occurs in *D. lageniformis* (fig. 2 *c*). But the chain of forms is rendered still more complete; for individuals are now and then met with, of the mitriform series (*D. acuminata*), with a couple of cornua placed on each side on the actual apex of the test (Plate XVI. fig. 8); so that between the mitriform and the oblique varieties under notice the compressed and oblique figure and commencing inversion of the lip constitute the sole difference.

Lastly, we arrive at the extreme limit of the oblique series, in which, however, there are no cornua; but excentricity of the aperture becomes greatest, and its entire margin is inverted so as to constitute a short tube extending upwards into the cavity of the test. This last character, singular as it appears, has its counterpart in the Entosolenian group of the Lageniform Foraminifera; and I am glad of the opportunity of stating that the generic separation of *Entosolenia* from *Lagena* is insisted on by Professor T. R. Jones and Mr. Parker for the same reasons that are here advanced, namely, that the character indicates only *varietal* distinction ('Introduction to the Study of the Foraminifera,' by Dr. Carpenter, pp. 157, 158).

The very singular helmet-shaped variety (figs. 5 *b*, 5 *c*), which may be regarded as the antithesis to *D. lageniformis*, is represented as it occurs in the Greenland material. In it we merely perceive, in its most exaggerated degree, the obliquity already so marked in the variety shown in fig. 5 *m*, the depression of the test, together with the inversion of the margin of the aperture, occurring in the early form shown in figs. 5 & 5 *m*, clearly proving how the latter connects *D. cassis* with the globular varieties.

One more transition in the Difflugian series remains to be noticed before I conclude this section of my subject. It is an important one, however, since it seems clearly to indicate that, whilst the animals of *Difflugia* and *Arcella* are generically identical, there is no such difference between their respective tests as can constitute more than a *subspecific* separation.

In the Difflugian test we constantly witness a structure similar to that first pointed out by Messrs. Jones and Parker as pervading the group of Foraminifera to which they have assigned the name of Lituolidæ. But we must bear in mind one point of difference—namely, that whereas in the Lituoline group the modification of material employed in the construction of the shell entirely supplants the normal calcareous material which is secreted by the animal, amongst the *Difflugiæ* there is no normal *mineral* secretion to supplant*. I allude to the composition of

* I am aware that the word "secrete" expresses more than we have

the test in *Difflugia* of arenaceous particles cemented together by a chitinoid exudation from the animal, precisely after the same fashion as the chitinoid and arenaceous elements of the shell are cemented together in *Lituola.* Indeed in some specimens of the more common varieties of *Difflugia,* in which the chitinoid matter assumes a sienna-tint, it is extremely difficult, if not impossible, to say, on mere inspection of the broken-up wall of the test, whether we have under our eyes a portion of a Difflugian test or a Lituoline shell *.

In *Arcella,* on the other hand, the test is almost invariably *only* chitinoid in its composition; and although we frequently meet with tests nearly devoid of mineral particles, and closely resembling that of *Arcella* in its hemispherical or depressed outline, central aperture, and inversion of the lip, a very small degree of skill enables us to perceive that the object before our eyes does not present the characteristic symmetrical reticulation of that form, but is in reality an osculant variety from the side of *Difflugia* †.

If we now turn to the *figure and plan of growth* of the tests, we shall, I think, perceive that these are analogous in the two forms.

Commencing with the earliest state of the Arcelline test, (unless I am much mistaken) *Arcella hyalina* (Ehr.), *Arcella patens* (Clapar. and Lach.), and several varieties of Orthosiran or Melosiran discs have all been confounded more or less with it. That this should have been the case is in nowise surprising when we consider the minute and almost invisibly hyaline character of the test of *Arcella* at this period. Without, however, asserting positively that this has been the case, I may state that minute forms answering precisely to the published characters of the Rhizopods (not the Diatoms) mentioned above have been

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here a warrant for assuming; but, keeping in view the fact that the calcareous or siliceous matters of which such structures as the shells of the Foraminifera and internal skeletons of the Polycystina are respectively formed are eliminated from the water in one condition, and somehow or other reproduced as an exudation from the animal in another, we certainly express the result by adopting the word, although the process by which it is brought about may be regarded as exceptional.

* The appearances presented under the microscope by the broken-up test of one of these *Difflugiæ,* or a shell of *Lituola,* are very similar to those visible, by the unaided eye, in the beautifully constructed cylindrical tubes of *Pectinaria*; and they indicate a degree of adaptative skill which, however wonderful it may be thought in the articulate animal, is doubly wonderful in the Protozoan.

† Such a variety is referred to by Ehrenberg (Infusionsth. Taf. ix. figs. *a*, *c*) as *Arcella aculeata,* showing how very closely *Difflugia Arcella* (Pl. XV. fig. 1 *y*) and the plain form of *D. globularis* resemble each other in character.

repeatedly observed by me, in which it was only by dint of extreme care in manipulation of the light, the focus, and the specimens themselves, aided by the employment of high magnifying power, that it became possible to perceive that, instead of the test being a simple cup-shaped disc, it was shaped like the mature *Arcella*—the plane surface being present, and at its centre the minute aperture through which the pseudopodial sarcode was protruded.

In somewhat older specimens, the figure of the Arcelline test admits of no doubt; but in these the convexity is generally very trifling (probably, as before stated, in consequence of the still extremely delicate texture), and the inversion of the margin of the aperture is but slight. At this stage, barring the presence of mineral particles in the test of the ordinary *Difflugia*, and the absence of obliquity in that of *Arcella*, there is nothing to distinguish one test from the other. The inversion of the lip is but a repetition of what has already been shown to take place in *Difflugiæ*; so is the depression of the test; whilst, lastly, the variety of *Arcella* to which the name of *A. angulata* has been given is nothing more than the common form of the mature Arcelline test pulled inwards at various points of its convex aspect by the action of the stolons, which are constantly seen extending from the posterior portion of the sarcode-body, and enable the creature to carry its test on its back, just as a snail carries its shell (Pl. XVI. fig. 36).

Under these circumstances, however convenient it might be to retain the two generic appellations, simply because we have become familiar with them, if we regard classification in its only legitimate light, namely, as a guide in the interpretation of the physiological differences prevailing through the organic world, we must either consent to forego convenience by breaking down the fictitious generic boundary-line which has hitherto been assumed to exist between *Arcella* and *Difflugia* or perpetuate a very serious error.

With regard to the means whereby the composite tests are built up, it may be recollected that, in the 'Annals' for last January (p. 78), I suggested the probability that in *Difflugia* the external portion of the test receives fresh additions either of chitinoid or mineral matter through an expansion of the sarcode-substance reflected back from the main aperture, or formed by the coalescence of sarcode-stolons which escape through one or more pores distributed here and there over its surface. This view appears to be substantiated in a great measure by the fact that in the ordinary forms, whatever may be the mineral composition of the superficial layer of the test, there is generally to be seen below this, and resting immediately upon the primary chitinoid wall of the chamber, a series of irregular micaceous-looking plates. Indeed it is difficult to conceive how additions could be made externally to the thickness of the test by any other method than the one indicated,—the accumulation of layer upon layer of mineral particles being, in some cases, carried to such an extent that the wall of the test attains considerable thickness and an outline so bold and rugged as to present the appearance, under the microscope, of a mass of coarse sandstone rather than a built-up chamber tenanted by a living organism.

I have never succeeded in actually witnessing the process of test-construction going on in *Difflugia*. But were the particles of mineral matter conveyed to their resting-places by the pseudopodia, it seems hardly possible that it should have escaped notice altogether ; and, on this account, I am rather inclined to think that, whilst the creature is enabled by means of these organs to select such particles as are best fitted for its purpose, they serve merely to drag the body towards the particles, and eventually to bring that portion of the test upon which they are destined to be lodged in contact with them.

No doubt this presupposes a selective power far in advance of any faculty we should *à priori* be inclined to attribute to organisms of so rudimentary a type. But to deny this power is simply to deny an established fact which can be accounted for in no other way. We have only to examine such tests as are represented in Plate XVI. figs. 9, 10, 16, 20, 22, &c., to satisfy ourselves that the collection of mineral particles of certain dimensions, and of certain kinds, must necessarily have been effected with a view to serve some particular purpose. But, wonderful in itself as this faculty must appear, I beg to draw special attention to it, inasmuch as it tends, in conjunction with other distinctions to which it is unnecessary for me at present to refer, to establish the impassable boundary-line betwixt the animal and the plant—between the manifestation of vital, chemical, and physical agencies on the one hand, and these combined with psychical agencies on the other. And I venture to say that, however stubbornly we may ignore this doctrine, simply on the score that it has heretofore defied our comprehension, the day will assuredly come when, with the assistance of a more perfect knowledge of organic life than we as yet possess, its accuracy shall cease to be impugned.

The next series of varietal modifications, in the order of their importance, is that involving the *materials* of which the Difflugian test is constructed.

I have, thoughout these observations, spoken of the exudation from the animal which constitutes the basis of every Rhizopodal test (and of which the test is exclusively made up in certain genera) as a *chitinoid* material. By this expression it is simply intended to convey that the material referred to presents as close an approach to the substance known as chitine as is determinable from the optical characters of portions far too minute to admit of chemical analysis ; and I believe I merely adopt a view very generally entertained by competent observers, when I give it this designation. But whatever may be the precise chemical composition of the substance, the name serves to indicate a well-known part of the structures ; and, to say the least of it, this is a higher quality than can be assigned to many of the scientific terms which are now and then submitted to the public.

In the majority of the Difflugian tests, this chitinoid material forms a continuous and smooth layer internally, it being on the external surface alone that mineral particles are impacted. It is also a most interesting fact, that no vegetable or extrinsically derived animal substances are employed for the consolidation of the test, and that the particles selected are, I believe invariably, of mineral nature. On the other hand, it is manifest that the selective power is carried to such an extent that colourless particles, sometimes quartzose, sometimes felspathic, sometimes micaceous, are always chosen* — the absence or presence of angularity in these particles being of course dependent on the condition of the sandy matter in each locality.

The particles would seem to be impacted into the chitinoid matrix just in the same way that a brick is pressed into the yielding mortar; and this too in so skilful a manner as to leave the smallest possible amount of vacant area; whilst in the specimens in which tabular or micaceous particles are used, these are sometimes disposed with such nicety that there is no overlapping, but the small fragments are placed so as to occupy the spaces left between the larger ones. Figs. 11, 15, 20, in Plate XVI., are examples of this kind †.

It is curious that even in pools or streamlets in which the deposits seem to consist almost exclusively of vegetable débris, the *Difflugiæ* still manage to find mineral matter sufficient for their purposes; whilst, as already stated, in those places where they run a risk of being washed away by running water, they reduce the chances of the catastrophe as far as possible by loading their tests with the largest particles and the greatest quantity of mineral matter. Figs. 9 & 10, the one from Greenland, the other from a little streamlet at Hampstead, are moderate examples of this loading, which, it may be remarked, is

* In Indian specimens I have occasionally detected the siliceous spicules of *Spongilla*.

† Plate XVI. will now alone be referred to, unless the contrary be expressly stated.

more frequent in the mitriform than in the globular series. It also takes place more frequently in certain varieties than in others of the globular series, as will be seen on reference to figs. 17, 18, & 27 on the one hand, and figs. 19, 20, 22, & 23 on the other.

But the selection of mineral particles is not confined to strictly inorganic substances. The *Difflugiæ* seem to know that in the valves of the Diatomaceæ are combined the properties best suited to their wants—that is to say, transparency and forms capable of being easily arranged,—at the same time that the diatoms occur as epiphytes on the aquatic plants upon which they themselves frequently find feeding-ground. And it is a remarkable circumstance that we can generally tell whether diatoms are or are not plentiful in a given locality by observing the share taken by them in the composition of the Difflugian tests. Thus, to cite an example close at hand, in the Hampstead pools the predominant diatoms are *Pinnularia* and *Eunotia*—the former of very large size, the latter extremely minute *. Hence the first is but rarely seen impacted into the tests, and when present it is of medium size. The second, however, constantly occurs, and, in the curious variety of test referred to as *D. spiralis*, and likewise in the globular and lageniform series, they often constitute a very large percentage of the mineral matter (figs. 18, 18*a*, 24*b*, & 32†).

In the Greenland mountain streamlets from which I obtained some of my specimens, Eunotias occur very abundantly, and under a remarkable variety of forms. In some tests they constitute the entire mass of mineral matter, and, as in the Hampstead material, pervade nearly every shape of test, though much less predominant in the depressed series (figs. 9 & 27).

I have now to speak of several novel modifications in the outward characters of the Difflugian tests which have heretofore been observed by me, for the most part amongst the varieties of the mitriform and lageniform series, and which I have been able, only within the past few months, to trace as an unbroken chain from the forms already described to those in which the chitinoid matrix presents no appreciable admixture with mineral matter.

The first indication of this very remarkable and instructive

* This diatom would seem to have been hitherto undescribed. It is stipitate, the valves being generally from $\frac{1}{2500}$ to $\frac{1}{1600}$ of an inch in length, and occurs in crowds around a filamentous "frond," appearing to be very generally distributed. An extremely minute *Navicula* also occurs, but is rarely employed in the construction of the test—thus affording another example of selective power.

† The two figures 24 & 24*a* are not intended to show these diatom-valves; but certain cylindrical or, as I formerly called them ('Annals,' June, p. 451), pellet-shaped cylinders, which will be more particularly referred to presently.

series of forms was detected by me last autumn in the Hampstead material, and described and figured in 'The Annals' for December 1863, under the name of *Difflugia pyriformis*, var. *symmetrica* (*loc. cit.* p. 458, plate 8. fig. 16). For facility of reference, I have again figured this form in the plate illustrative of the present section of my subject (figs. 26 *a, b, c,* & *d*). As previously stated, the test, instead of being built up of irregular mineral particles so as to impart a rugged outline, is entirely made up of hyaline rectangular plates, arranged with the greatest regularity in consecutive transverse and longitudinal rows—the smaller plates being thus disposed towards the extremities, whilst the larger ones occupy the central and widest portion of the structure. It was stated at the same time that the chemical composition of these plates had not been ascertained by me (the reason being that they do not occur in sufficient quantity to render experiment practicable), but that there was ground for believing their nature to be crystalline and siliceous—firstly, because the plates resisted the effect of the heat employed in mounting the specimens, and their angles were most perfect, and secondly, because they presented no coloration when seen with the aid of the polarizer.

Since the date of my first examination of this form, I have succeeded in procuring a considerable number of similar specimens from the same locality; but, beyond confirming my previous statement in every particular, I have nothing to add, save that the test is more or less compressed laterally, whereby an elliptical outline is given to the section and aperture (figs. *c, d,* & *e*).

The true nature of these rectangular plates will, I believe, become manifest as I proceed with the description of the transitional states which intervene between this, the most aberrant kind of composite surface-configuration to be met with amongst the tests of the *Difflugiæ*, and the least aberrant forms, which are represented at figs. 30 & 31.

Fig. 27 represents the first form to be noticed. In this there is an admixture of at least four *apparently* distinct sets of bodies attached to the surface of the test. These are not arranged with the symmetrical order observable in the rectangular plates; but this may be accounted for, inasmuch as the specimen (which in this instance is a solitary one) was mounted in balsam in the material in which it occurred before I had become aware of its existence; and hence, in all probability, the pressure of the glass cover of the slide caused a certain degree of displacement. Be that as it may, it is quite manifest that we find associated together in the same individual, first, rectangular plates, secondly, others in which the plates are produced in one direction at the same time that one of the angles is truncated obliquely, thirdly, plates approaching in outline rectangular prisms; and lastly, bodies in which the tendency to crystalline outline is lost and they pass into oblong colloid discs somewhat depressed at their centre.

We now come to the forms shown at figs. 28 & 29, in which the surface of the tests is studded with the oblong bodies, some of which, however (as is more manifest in the larger specimen), exhibit a faint but nevertheless definite approach to elongated hexagonal prisms*. These measure about $\frac{1}{2500}$th of an inch in length. They are unmixed with any other bodies, and arranged side by side with a certain degree of regularity. In these the central depression is also distinct. The larger specimens (fig. 29) are from Greenland. The smaller, in which the discs are not more than about $\frac{1}{3000}$th of an inch in length, are from Hampstead.

In fig. 33, which also represents a tolerably frequent variety of test, the discs attain their maximum of regularity as regards shape: all are circular, or very nearly so, and exhibit the central concavity in a very marked manner; indeed they resemble blood discs in several particulars, but of course the resemblance is merely apparent. They are of varying sizes, the largest averaging about $\frac{1}{2500}$th, whilst the smallest are not more than $\frac{1}{10000}$th of an inch in diameter, the larger ones being generally surrounded by groups of the smaller, although, as seen in a number of specimens, there is evidently no particular order in which they are arranged, beyond that resulting from their taking up positions side by side, and all, without exception, resting on their flat surfaces.

But it is in the series of forms already referred to as built up in a great measure of minute diatoms that we find the clue to the origin of the colloid discs and rectangular plates. In figure 32 the diatoms, as will be seen, are interspersed amongst the circular discs. The very important fact reveals itself, however, that some of the diatom-valves are becoming gradually metamorphosed, that is to say, exhibiting a gradual passage from the typical outline of the little *Eunotia* to one more closely approaching an irregular cylinder, the cylinder then passing into the elongated disc, which is at times distinctly hexagonal, and finally the elongated disc passing into the circular one. The specimen figured is not so calculated to show the transitionary as the unmetamorphosed state of the diatoms; but in some individuals, and more especially in crushed specimens of these tests, every stage of transition may be clearly distinguished. As

* It is not improbable that the tendency to assume this hexagonal form may result from pressure of the discs one upon the other.

already stated, the appearances just indicated are to be found not only in the lageniform and mitriform, but also in the globular series, and in the exceptional variety *Difflugia spiralis*.

Lastly, I may mention that in certain individuals (as for example in figs. 13, 23, 24, & 24 *a*) the whole of the test is covered with minute cylindrical rods evidently of similar origin. Sometimes these little cylinders are straight, sometimes irregularly curved; but, as in the former examples, they are arranged side by side, and without any very distinct regularity *.

It has been already stated that no effect is produced by the rectangular plates when seen by polarized light. When, however, the discs (which in common with the rectangular plates and cylindrical bodies are themselves perfectly colourless) are seen by polarized light, the alternating changes of tint are not only distinctly visible over the test generally, but to the same extent in each particular disc,—thus indicating that the effect is not due to the presence of micaceous or other mineral films such as usually underlie the external coarse layer of sandy particles—a fact which is verified when such forms as those now under notice are broken up under the microscope.

The inference which I draw from this singularly complete series of transitionary forms is, that the chitinoid basal substance of the test, or (as is quite possible when we take into consideration the facts I shall presently adduce with regard to the mode in which mineral particles are arranged by an external sarcode-layer such as we see in *Gromia*) a portion of the viscid sarcode mass, combines, under the law of "molecular coalescence" †, with the siliceous or other mineral elements, and thus serves to produce all the transitionary colloid bodies which occur, from the first alteration in shape of the mineral particles themselves, to the development of the crystalline tablets which were first described. One thing is quite manifest, namely, that the whole series of bodies now under notice are derived in some way from the animal, and *not* directly from the medium in which it lives; for none are traceable in a free condition in the material in which the specimens occur. On the other hand, notwithstanding the selective and adaptive faculty already shown to belong to the Rhizopod, we are not warranted in assigning to it a special *formative* power. The origin of the minute crystalloids, so abundantly present in the Amœban and Difflugian forms generally, is thus also accounted for; and step by step we are arriving at a knowledge of the mode in which the vital and

* These bodies were accurately described by me in the 'Annals' for December 1863, p. 456.

† See Mr. Rainey's valuable papers on "Molecular Coalescence" in vols. vi. and vii. of the Journal of Microscopical Science.

physical forces combine, probably in every structure called organic, to build up the tissues of which the animal and vegetable kingdoms are composed.

But another important fact bearing on the series of forms represented in figs. 26–33 must now be noticed. In these the tests are sometimes so compressed as to give the aperture, when the structure rests on one side, the undulating appearance exhibited more particularly in figs. 27, 29, & 30. But more frequently, the tests are not compressed, and the aperture presents the ordinary circular or nearly circular outline. Whilst endeavouring to gain a clear end-view of one of the undulating apertures, namely the one shown in fig. 30, I found it to be closed as shown in fig. 30 *b*, and, further, the sarcode-mass gathered into a spherical mass, occupying the middle half only of the test, the transparent texture of which, in the specimen referred to, enabled me to discover that this mass was prevented from escaping by a well-defined membranous diaphragm which seemed to be attached around the interior of the wall of the test a little in front of its broadest portion. The true significance of the spherical body would, however, probably have escaped me, but for the occurrence of a hyaline crescentic space between its anterior convex part and the interior of the diaphragm, the convexity of which was also directed outwards.

Here then it became evident that a process of encystation precisely similar to that described by me as occurring in *Amœba* ('Annals,' November 1863, p. 336) had taken place in a testaceous form, and that the test is neither the analogue nor the representative of the cyst of the naked forms, but must be regarded as an entirely distinct portion of the structure.

Now, how far the peculiar external features witnessed in the series of tests above alluded to may be associated with the decrease of the ordinary process of nutrition incident on encystation, and may thus tend to render the chitinous material of the test free to be acted on by purely chemical or physical forces, I am at present unable to say. It must not be forgotten, however, that the complete withdrawal of the body of the animal into the interior of the test, and its envelopment by the cyst, would necessarily prevent the diffusion of any portion of the sarcode-substance over the external surface of the test, and hence external influences would act directly on the test. But the repeated occurrence of similar tests with open apertures, and with the animal, at all events as yet, unimpeded by the cyst, seems clearly to indicate that the one set of conditions is not necessarily incompatible with the other. On the other hand, I am able to state that the singular characters presented by the tests and the process of encystation referred to are not confined to a single variety or series of varieties, but pervade the whole group, inasmuch as I have met with tests of the mitriform series containing the encysted animal, the posterior third of which was still covered with large unmetamorphosed sandy particles, whilst the anterior two-thirds were studded with the elongated discs of figs. 28 & 29. In these tests the apertures were in every respect similar to the one figured at fig. 30 *b*, thus proving the transition from the common pyriform Difflugian test to that variety in which all appreciable trace of mineral matter is lost. The above facts also enable us to account for the very common and provoking occurrence with which most persons who are acquainted with the freshwater testaceous Rhizopods must be familiar, namely, the frequent impossibility of getting the animal to emerge from the ball into which it rolls itself in the interior of the test.

These partially and wholly closed orifices are instructive, however, from another point of view, namely, from their proving that, even in the most mature state of the Difflugian test, its outline is liable to change, and hence that the external mechanical agencies to which I have adverted in the case of *D. spiralis* may actually produce the duplicature of its test.

We now come to modifications in *size*. Were more cogent reasons wanting why mere measurements of the tests of the *Difflugiæ* should cease to be regarded as affording a basis for specific distinction, the facts already advanced to show how largely the whole of the external characters of the tests are influenced by outward conditions, which are themselves of the most fluctuating nature, would, as I conceive, amply suffice for the purpose. It is well known, however, that amongst the freshwater testaceous Rhizopods, the actual bodies of the animals occupy but a small and indeterminate portion of the chamber in which they are encased; and I presume no one will maintain the existence of a fixed ratio between the animal and its test. Should fission occur in *Difflugia*, as we know it does in *Amœba*, the existence of any such determinate ratio becomes still less admissible. It is therefore obvious that, in resorting to the measurement of the test as a criterion of the dimensions of the animal, the process must be altogether fallacious. But even amongst the higher tribes of the animal and vegetable kingdoms, notwithstanding the facilities these offer for ascertaining when the extreme limits are arrived at either in growth or age, size is not accepted as a test of specific unity or distinctness, unless it be accompanied by such structural or functional changes as can be shown to have exerted an influence in modifying it. But amongst the microscopic forms of life we have hitherto entirely failed to trace any constant indication by means of which it is possible to determine whether a specimen under examination be a mature or an immature one. The frequent occurrence in the muddy deposits of effete tests of *Difflugia* and other testaceous forms throws no light on this subject; for there are no means of knowing whether such tests have been shed, according to a periodically recurring influence, or are merely left after the death of the occupant at a certain stage of its existence or through accident; and until such an indication is forthcoming, all specific distinctions based on mere size must therefore be valueless. These remarks apply, however, only to the measurements of such objects as the tests of the *Difflugidæ* or other Rhizopods, and not to special organs, which, as they rarely vary to any great extent, whether in young or old individuals, may hence be frequently recognized by their dimensions alone. But even in such cases the aid afforded by measurement must continue to be counterbalanced so long as no uniform scale is adopted both in descriptions and figures, and a certain amount of calculation is necessary before we can arrive at the fraction which expresses what we desire to ascertain.

Of one fact I have had abundant opportunity of satisfying myself, namely, that the dimensions of the Difflugian tests, in like manner with their plan of growth and external characters, are modified to an extraordinary degree by the nature of the localities in which they happen to be found,—still water, with an abundance of food in the shape of minute Algæ and Infusoria, constituting the most favourable conditions; whilst variations in climate would seem to influence their growth and increase only in an indirect manner, namely, by increasing or diminishing the quantities of sustenance.

As stated in an early portion of these observations, I have met with representatives of every variety of the freshwater testaceous Rhizopods in each of the remote regions of the globe in which I have searched for them. It is well known that Diatoms, a group of organisms holding a position in the vegetable kingdom probably parallel to that held by the Rhizopods in the animal, are to be found in all climates. It is an interesting fact, however, and one which was somewhat unlooked for, that, under the conditions prevailing in high northern latitudes, the long-continued congelation to which the whole of the lower forms of life are annually subject seems to exercise no destructive effect; for not only are the freshwater Diatoms and Desmidians* very plentiful, but also the whole of the freshwater

* In one locality in West Greenland, at an elevation of probably about 1000 feet above the sea, I obtained no less than twenty-six species and varieties of Desmidians. Had my object been to collect this kind of organism, the number might doubtless have been largely augmented.

Rhizopods. Indeed, in point of number and variety, the latter were quite as abundant in Greenland as in Bengal; whilst the dimensions of the Greenland specimens were only inferior to those of some of the most highly developed varieties from the Gangetic Sunderbunds, to which I have already drawn attention.

I have now to speak of the last and certainly the least important of the modifications, namely, *colour*. My remarks on this head shall, therefore, be very brief.

Where the water in which the *Difflugidæ* occur is pure, and the vegetable matter contained in it not undergoing decay, the tests of these organisms, as might be inferred from the nature of the materials of which they are composed, are colourless. Sometimes mud or disintegrating organic matter adheres to the tests, and imparts a tint; but it must be obvious that this bears no relation to the animal or even to its test, and is therefore as variable a character as it is accidental. The chitinoid substance, however, which constitutes the basis of the matrix of the tests, generally speaking, exhibits a delicate sienna-tint; but sometimes it assumes a darker shade, and hence imparts a similar colour to the entire test. But, as this peculiarity pervades the entire series of forms, it furnishes no distinctive character. In some cases, as, for example, where *Difflugidæ* are collected in the red muddy deposits met with at Hampstead and elsewhere, the tint above referred to may be imparted from without; and since we know that in *D. Arcella* the young tests are colourless, whereas the mature ones gradually become brown, it is reasonable to suppose that the effect depends on age or exposure. But, for the reasons assigned, whilst the deepening of the colour of the test in *D. Arcella* enables us to form some estimate of the age of a specimen, in the other *Difflugidæ* the effect takes place to such a limited extent as to be unavailable for this purpose. It only remains to be mentioned that the colour of the animal within the tests varies, from the pale gray of granular sarcode to green or yellow or brownish red; but, in my experience, I have invariably been able to trace all the last-mentioned modifications of tint to the nature of the food which the organism has incepted.

My present limits do not admit of more than a cursory allusion to the *Euglyphidæ*. Indeed it would be impossible to give a satisfactory outline of their characters and relations without introducing several new and undescribed marine forms which would obviously be out of place in the present memoir. I shall confine myself, therefore, to stating that, since no doubts have arisen concerning the identity of the animal in the several genera and species into which the heretofore described members of this group have been subdivided, and mere differences in the figure or surface-markings of the test cannot be regarded as denoting generic distinction, I am unable to perceive any valid ground for separating *Cyphoderia* (Schlumb.), *Difflugia Enchelys* (Ehr.), and *Lagynis** (Schultze) from the typical genus *Euglypha.*

The case is different, however, when we find that the test of one section of a subfamily is invariably chitinoid, and of another as invariably siliceous. I accordingly deem it necessary to place *Cadium* (Bailey)—a form I have met with in abundance, and the true siliceous nature of whose test I can certify—in a distinct genus, along with the marine forms to which reference has been made.

Under this view of the general affinities of the testaceous freshwater Rhizopods, *Difflugia Arcella* may therefore be regarded as the connecting link between the *Difflugidæ* and *Euglyphidæ*; whilst a very cursory examination of the forms of the latter subfamily, in which the general axis of the test and of its aperture are not coincident, will serve to show that this peculiarity is merely the counterpart of the obliquity that has already been shown to pervade the tests of the marsupiform series of the *Difflugidæ,* and, lastly, that the apical appendage which frequently makes its appearance in *Euglypha margaritacea,* and is carried to such an extent in one of the new oceanic forms—namely *Cadium caudatum* (Wall.)—as to constitute a tail-like organ several times the length of the body of the test, is in like manner merely the homologue of the apical appendage of *Difflugia acuminata* and the horned varieties of the globular series.

But to conclude. Assuming from the facts which have been advanced that the shape, material, size, and colour of the Difflugian tests furnish characters so singularly prone to accidental variation as to yield no trustworthy criterion of generic or even true specific distinctness, and recalling to mind once more that the animal is in every instance specifically the same, it appears to me impossible to arrive at any other conclusion than that the whole of the *subspecies,* as well as their intermediate varieties (widely though some of these appear to differ from others in external features), have not only been originally derived by direct descent from a single progenitor, but do still continue to be produced by direct descent from varieties which have become permanent, and may, one and all, still be produced from a common archetype under the varying conditions to which these lower forms of animal life are universally subject.

* My knowledge of this Rhizopod is derived exclusively from the description and figures published by its discoverer, Professor Schultze (Ueber den Organismus der Polythalamien, p. 56, taf. 7 & 8); and, allowing due weight to the difference of habitat, I can perceive no valid reasons for considering as only apparent the resemblance to *Euglypha curvata* (Perty) to which allusion is made in the definition.

In accordance with the views advanced, the whole of the Testaceous Proteina may be accordingly arranged as follows:—

- Order PROTEINA.
  - Families.
    - ACTINOPHRYNA.
      - Subfamily. *Euglyphidæ.*
        - Genus 1. *Euglypha* (Duj.)
          - Species 2.
          - *E. alveolata* (Duj.).
          - Subspecies, *E. Enchelys*=*D. Enchelys* (Ehr.) =*Trinema acinus* (Duj.).
          - *E. margaritacea* = *Cyphoderia margaritacea* (Schlumb.).
          - var.? *E. baltica*=*Lagynis baltica* (Schultze).
        - Genus 2. *Cadium* (Bailey).
          - Species 1.
          - *Cadium caudatum* (Wall.).
          - var. *C. marinum* (Bailey).
    - AMŒBINA.
      - Subfamily. *Difflugidæ.*
        - Genus 1. *Difflugia.*
          - Species 1.
          - *D. proteiformis* (Ehr.).
          - Subspecies 1. *D. mitriformis* (Wall.).
            - var. α. *D. acuminata* (Ehr.).
            - ,, β. *D. spiralis* (Leclerc).
            - ,, γ. *D. pyriformis* (Perty).
            - ,, δ. *D. lageniformis* (Wall.).
          - Subspecies 2. *D. globularis* (Duj.).
            - var. α. *D. tuberculata* (Wall.).
            - ,, β. *D. aculeata* (Ehr.).
            - ,, γ. *D. corona* (Wall.).
          - Subspecies 3. *D. Arcella* (Ehr.).
          - Subspecies 4. *D. marsupiformis* (Wall.).
            - var. α. *D. cassis* (Wall.).

Genus DIFFLUGIA (Leclerc).

Characters. Animal a testaceous Amœban. Pseudopodia cylindrical or digitate. Test chitinoid, or chitinoid with addition of mineral matter.

Species 1. *D. proteiformis.*

Characters of test. Form of embryonic test subspherical, from $\frac{1}{5}$th to $\frac{1}{8}$th of the diameter in one direction being truncated and constituting the aperture. Form of mature test extremely variable.

Subspecies 1. *D. mitriformis* (Wall.).

Characters. Test mitre-shaped, more or less inflated at posterior extremity, and without any fixed ratio between its length and breadth.

Var. α. *D. acuminata.* Apex of test acuminate.

Var. β. *D. spiralis.* Anterior third of test bent back upon its body, so as to present a retort-shape*.

Var. γ. *D. pyriformis.* Shape varying from the pear- to the balloon-shape.

Var. δ. *D. lageniformis.* The same as the last, but with a lip everted in varying degrees. The most highly developed variety of this form, and one that might pass for the archetype of the Roman amphora.

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* It is somewhat of a misnomer to call this form *spiral*: as already stated, the turn does not extend further than that of a retort.

Subspecies 2. *D. globularis* (Duj.).

Characters. Test more or less globular, from $\frac{1}{6}$th to $\frac{1}{8}$th being truncated and forming the aperture. Margin of the latter plain or crenulate. Test occasionally furnished with cornua, sometimes arranged symmetrically, sometimes the reverse; their number variable. Test occasionally depressed vertically and excentrically.

Var. *α*. *D. tuberculata.* Surface of test covered with subhemispherical nearly equal-sized elevations, which give it a mulberry-shape. In some tests there are corresponding hollows on the interior of the chitinoid wall.

Var. *β*. *D. aculeata.* Test generally compressed excentrically, so that the aperture is also excentric. Margin of aperture generally inverted to some extent, but not always. Surface of test either furnished with a varying number of finger-like cornua, or plain. The cornua for the most part arranged in a halfcircle round the posterior half of the test; but their position, as well as shape, is very variable.

Var. *γ*. *D. corona.* Test crown-shaped, furnished with from three to eight conical cornua placed around its posterior third. Margin of aperture regularly crenulate; number of crenulations variable.

Subspecies 3. *D. arcella* (Ehr.).

Characters. Test chitinoid, rarely if ever presenting mineral matter on its surface, which is studded with regular but very minute hexagonal reticulations. Form presenting varying degrees of plano-convexity, the convexity at times amounting to that of a hemisphere; the aperture small, invariably occupying the centre of the plane surface, and its margin being more or less inverted.

Subspecies 4. *D. marsupiformis* (Wall.).

Characters. Test varying, *in the side view,* from that of a slightly excentric and depressed hemisphere to the pyriform outline, but with this peculiarity, that the aperture, as seen in this view, occupies a position *on one margin* of the pyriform figure, and extends from the centre to a point approaching the *anterior* or narrowest portion of the test. In the *front view,* the test is pouch-shaped. Margin of aperture markedly inverted. The mature test generally presents from three to six cornua arranged over its posterior third.

Var. *α*. *D. cassis* (Wall.). Merely a small and extreme variety of the marsupiform test, but rarely presenting the cornua.

On comparing the above arrangement and characters of the *Difflugidæ* with the figures in the accompanying plates to which attention is directed, there will, I presume, be but little difficulty in recognizing the points from which the predominant groups of varieties take their origin, and in tracing the gradations passed through by the most aberrant forms. I have deemed it preferable to represent the groups as diverging from points equally distant from the common centre or archetype of the whole than as clustering round those points, for reasons which have been already given, but which it is perhaps desirable now briefly to recapitulate.

As repeatedly stated, the entire series of Difflugian tests are constructed by animals which, with no known exception, are *specifically* identical. *A priori*, therefore, there is nothing improbable in the supposition that the entire series, in their earliest condition—that is to say, when the chitinoid exudation, of which the test is entirely composed at that period, first makes its appearance around the sarcoblast—are identical in form. But we have no need to assume the fact, for observation would seem to prove it. If this be granted, only one other condition is essential to the establishment of the doctrine that the entire series, not only in time past may have descended genetically from a single progenitor, but, what is of far greater moment, that they may still continue to be developed from a typical form common to all, —this condition being that the chain of transitional varieties should be so unbroken, and that there should be such a *radiation of characters* at every step, as to render it impossible to detect a character or set of characters which can be said to belong exclusively to a solitary form.

Now this is precisely what observation teaches us when we study forms obtained from a sufficiently wide geographical range. For, as has been already shown, we not only then find that the unimportant gaps sometimes discernible between contiguous varieties are bridged over, but, if we note the differences in the external conditions by which the organisms are surrounded, we are able, generally speaking, to trace a relation between the varietal form and the agencies which have affected it.

But, although there is good reason to believe that these conclusions are correct, we must never lose sight of the fact, that under those peculiarities in the physical conditions which are inherent in every geographical area, and must therefore be regarded as constant in their operation, the repetition of certain varietal forms, to the exclusion of others, must also be constant. In this sense, but this sense only, can species and subspecies be established amongst the *Difflugidæ*. *The animal does not vary; but it modifies the architecture of its habitation and the mineral material of which that habitation is in a great measure constructed, in obedience to local conditions, and in the manner best fitted to meet its requirements.*

It only remains for me to state that the universal distribution of these organisms, the ease with which they are obtained, their simplicity of structure, and the comparatively small number of types into which they seem to resolve themselves render them singularly fitted to throw light on the laws which regulate the variation of species. For, however true it is that these lowest animal forms are prone to variation in an unprecedented degree, this cannot surely be advanced as a plea for assuming that the laws which govern specific variation amongst the higher orders of creation must necessarily be of a distinct nature.

Kensington, Feb. 19, 1864.

EXPLANATION OF THE PLATES.

Plate XV.

This Plate is designed to show the order in which the four subspecies of *Difflugia proteiformis* arrange themselves around a common archetypal or embryonic centre; and their several varieties may be supposed to pass transitionally from one subspecific type to the other. It may be mentioned that none of the figures in either of these plates are diagrammatic, except the dotted half of figure 3 *v* in Plate XV.; and, with the exception of the central figure (fig. 1) of Plate XV., which is magnified about 800 diameters, that the whole of the other figures in both Plates are magnified from 200 to 300 diameters.

Fig. 1. Embryonic test of *Difflugia* from which the entire series take their origin, its diameter being about $\frac{1}{1600}$th of an inch, and the aperture formed by the truncation of from $\frac{1}{5}$th to $\frac{1}{8}$th of the diameter in one direction.

Fig. 2. The early state of the variety *D. mitriformis*, passing through 2 *p* and 2 *q* to the inflated form of the same variety, which then passes into the globular series (4 *h*), and through such forms as 2 *a* and 2 *b* to the extreme variety of this series, namely *D. lageniformis* (2 *c*). In this form the eversion of the lip of the aperture attains its maximum limit.

Fig. 3. Another young test of the mitriform series, passing in one direction into *D. spiralis* (3 *v*), in another exhibiting the various forms of *D. acuminata* (figs. 3 *a*, 3 *b*, 3 *c*), and in fig. 3 *s* merging into the variety called *D. pyriformis*.

Fig. 4. Early stage of the globular series. Fig. 4 *h* represents the typical subspecies *D. globularis*; fig. 4 *g*, the allied variety *D. tuberculata*; whilst fig. 4 *a* shows the occurrence of a crenulate aperture in the typical form, and, hence, the transition to the horned variety with the crenulate margin, *D. corona*. In this variety the number of horns and also of crenulations varies considerably. Finally, in fig. 4 *k* we observe the incipient obliquity in the axis of the globular form which suffices to render the position of the aperture excentric, and the horns met with in *D. corona*, but generally (as seen here) occupying only one-half of the test. This is the form referred to by Ehrenberg as *Arcella aculeata*.

Fig. 5. Early state of the oblique series (subspecies) to which I have given the name *D. marsupiformis**. Figs. 5 *a*, 5 *d*, 5 *e* are front and side views of the plain variety, showing great excentricity of the aperture, great vertical depression, and the *inversion* of the lip. Fig. 5 *m*, a horned variety of the same, closely spproaching the aculeate variety of the globular series (4 *k*). Figs. 5 *b* & 5 *c*,

* *Marsupium*, a pouch.

front and side views of the extreme variety, *D. cassis**, in which it will be seen that the characters of the marsupiform series attain their maximum development. The well-marked *inversion* of the lip and the extreme excentricity at once denote this form as being the furthest removed from that in which the lip is everted, namely *D. lageniformis* (2 *c*).

Lastly, fig. 1 *y* represents *D. Arcella* as a subspecies springing directly from the embryonic form. In it we perceive the reappearance of the inverted lip, whereby it is allied to the marsupiform series, and the vertical depression which, in some of the plain globular forms, renders it so difficult to determine whether the specimen presenting it is an aberrant *D. Arcella* or *D. globularis*; whilst at fig. 1 *z* is given a member of the allied Actinophryan subfamily, the *Euglyphidæ*, related to *Difflugia Arcella* both in virtue of its purely chitinoid test and the nature of the surface-marking in one of the species (*E. margaritacea*). *Difflugia Arcella* hence constitutes the connecting-link between the two subfamilies.

Plate XVI.

Fig. 1. Side view of a young specimen of the subspecies *D. globularis*; 1 *a*, front view, showing aperture.

Fig. 2. Side view of somewhat advanced state of the same; 2 *a*, front view.

Fig. 3. Side view of the early stage of the oblique or marsupiform series; 3 *a*, front view.

Figs. 4 & 4 *a*. Same views of a still more advanced stage of the same.

Fig. 5. Side view of horned variety of *D. marsupiformis*; 5 *a*, front view.

Fig. 6. *D. cassis*, side view; 6 *a*, front view.

Fig. 7. *D. mitriformis*, showing presence of the usual sandy granules on the posterior four-fifths of the test, whereas the anterior fifth is composed of chitinoid cylinders. (This form was figured by me, but very imperfectly, in the 'Annals' for June 1863, Pl. 10. fig. 12.)

Fig. 8. Two-horned specimen of *D. mitriformis*.

Fig. 9. *D. pyriformis*, from Greenland, showing how completely the test is made up of frustules and valves of diatoms (*Eunotia* and *Tabellaria*).

Fig. 10. Common form of *D. pyriformis*, showing moderately large sandy granules.

Fig. 11. *D. acuminata*, made up of tabular mineral particles.

Figs. 12, 12 *a*, 12 *b*, 13 *a*. Small specimens of mitriform and acuminate series. In fig. 12 a crystalline body has been added to the test.

Figs. 13 & 14. Oblong variety, showing the apertural band.

Fig. 15. *D. lageniformis*, showing incipient eversion of lip.

Fig. 16. *D. lageniformis*, mature specimen, showing hyaline everted margin of the lip.

Fig. 17. *D. globularis*, typical form, but made up of large sandy particles.

Fig. 18. *D. tuberculata*, mineral matter consisting, in a great measure, of minute diatoms. The test of this form is mulberry-shaped.

Fig. 19. *D. corona*, front view, showing crenulate margin of aperture; a six-horned variety.

Fig. 20. A somewhat smaller four-horned variety; side view.

Fig. 21. *D. globularis*, from Greenland, chiefly made up of minute diatoms.

Fig. 22. Plain variety of *D. aculeata*, showing the transition from the plain globular to the oblique form, and the incipient inversion of the margin of the aperture.

* *Cassis*, a helmet.

Fig. 23. Six-spined variety of *D. aculeata.*
Fig. 24. Front view of *D. spiralis.* Test composed of chitinoid cylinders. 24 *a,* side view of the same. 24 *b,* a portion of a test, showing the intermixture, in some cases, of minute diatoms.
Fig. 25. *D. spiralis.* In this specimen, the test is entirely made up of ordinary mineral particles.
Fig. 26. *D. symmetrica,* showing the rectangular hyaline plates: *a,* form of aperture; *b,* a more compressed specimen, in which the aperture (*e*) is nearly closed; *d,* a few detached plates.
Figs. 27 to 33 represent the series of forms exhibiting the transition from the ordinary mineral and chitinoid elements of the test to the evolution of the colloid discs. (See pages 231–234.)
Figs. 34 & 35. Varieties of *D. Arcella.*
Fig. 36. Puckered test of *D. Arcella,* which has hitherto been regarded as a distinct species, under the name of *D. angulata.*
Fig. 37. Front view of *D. Arcella.* In all these specimens the inverted lip is seen. Fig. *a* shows the invariably hexagonal pitting or reticulation of *D. Arcella.* (This can only be made out, however, in a mounted and crushed test, under a high power.)
Fig. 38. Young test of *D. Arcella.*
Fig. 39. This figure represents two *Difflugiæ* apparently united by their orifices in the manner which has been regarded by some writers as indicating "conjugation." The remarkable feature in the present example is, that the supposed conjugative act is being performed by individuals which, by the same writers, have been regarded as constituting distinct species.
Fig. 40. In this case, a specimen of *Amœba villosa* was seen to seize the pseudopodia of the *Difflugia,* and force the greater portion of its own body into the Difflugian test. After a time it again emerged, the villous organ, which had become concealed within the test, being the last portion to leave it.
Figs. 41 to 45. Varieties of *Euglypha.*
Fig. 46 & 46 *a.* Side and front views of *Euglypha Enchelys.*
Fig. 47. Bengal variety of same.
Fig. 48. *Euglypha margaritacea* (Stony Stratford). Fig. *a,* showing the manner in which the test is made up of minute chitinoid discs, so arranged that each one is united to those surrounding it by six equidistant connecting bands. In *Difflugia Arcella* the test almost invariably fractures through the hexagonal spaces, as seen in fig. 34 *a.* In *D. margaritacea,* the line of fracture as invariably traverses the spaces *between* the discs, proving that they are the thickest and strongest portions of the structure.

BIBLIOGRAPHICAL NOTICES.

The Natural History of Tutbury. By Sir Oswald Mosley, Bart., D.C.L., F.L.S. *Together with the Fauna and Flora of the District surrounding Tutbury and Burton-on-Trent.* By Edwin Brown. London: John Van Voorst, 1863.

As Englishmen, we of course have a vested interest in all that concerns "bitter beer," and accordingly, as English naturalists, the physical peculiarities of the district around Burton-on-Trent, in which the best of that blissful beverage is brewed, should have a double interest to us. We must therefore briefly record our thanks